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**WIRELESS REALLY
EXPLAINED**



FOULSHAM'S WIRELESS GUIDES

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FOULSHAM'S WIRELESS GUIDES

**WIRELESS REALLY
EXPLAINED**

BY
P. J. RISDON

**A NEW EDITION
ENTIRELY REVISED**

FULLY ILLUSTRATED

LONDON
W. FOULSHAM & CO. LTD.

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PREFACE TO REVISED EDITION

A WIRELESS-SET is more than a mere instrument for the reproduction of speech and music. It represents the outcome of one of the most remarkable and epoch-making discoveries of modern science, and the more one learns about the working of a wireless-set the more marvellous it seems.

Nearly everyone nowadays knows how to receive a broadcast programme by switching on a radio-set and operating one or two simple tuning controls. But the whole affair of broadcasting, which has now become such an integral part of everyday life in practically every civilized country in the world, assumes an aspect of new and vital interest when one comes to investigate the many wonderful processes involved in transmission and reception by wireless.

The purpose of the present volume is to explain, in as simple terms as possible, the main principles underlying wireless communication, and how broadcast transmission and reception is carried out.

CONTENTS

CHAPTER	PAGE
I. ELECTRICITY AND MAGNETISM	9
II. WIRELESS WAVES	17
III. THREE-ELECTRODE RADIO VALVES	25
IV. CHARACTERISTIC VALVE CURVES— AMPLIFICATION AND RECTIFICA- TION	33
V. INTERVALVE COUPLING DEVICES	47
VI. BROADCAST TRANSMISSION	57
VII. HOW A TYPICAL RECEIVING-SET WORKS	64
VIII. MAINS-OPERATED VALVES	73
IX. GRAMO-RADIO REPRODUCTION	77
X. SHORT-WAVE WIRELESS	81
XI. PRACTICAL RADIO HINTS	85
APPENDIX : SYMBOLS USED IN WIRE- LESS CIRCUIT DIAGRAMS	92 *

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I.	ELECTRICITY AND MAGNETISM	9
II.	WIRELESS WAVES	17
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VIII.	MAINS-OPERATED VALVES	73
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	APPENDIX : SYMBOLS USED IN WIRE- LESS CIRCUIT DIAGRAMS	92

WIRELESS REALLY EXPLAINED

CHAPTER I

ELECTRICITY AND MAGNETISM

ALTHOUGH a detailed knowledge of electricity and magnetism is by no means essential to the full enjoyment of radio reception, it is necessary to understand at least a few of the elementary facts about the electrical and magnetic phenomena underlying the science of wireless before one can derive the maximum interest from the use of a receiving set. Before attempting to explain the elements of wireless, therefore, one must deal briefly with some simple principles of electricity and magnetism.

Anything which offers very little resistance to the flow of an electric current is called a *conductor*. All metals are conductors, copper being one of the best. Water, too, is a conductor, to some extent, and so is the earth itself.

On the other hand, anything which offers a very great, or infinite, resistance to the flow of an electric current is called an *insulator*. Ebonite, mica, bakelite, waxed paper, and glass are among the principal insulating substances used for wireless and electrical purposes. Dry air, of course, is an excellent insulator.

When an electric current passes through a conductor—say through a wire—it sets up what is termed a *magnetic field* round the conductor. The truth of this statement is proved every time we ring an electric bell, but it is quite a simple matter for the reader to verify it by experiment. Roll a piece of stiff paper into the form of a small cylinder a few inches long, and wind a single length of insulated copper wire round it from end to end, with the turns close together, but not overlapping. Attach one end of the wire to one of the terminals of an electric dry cell or of an accumulator, and the other end to the terminal of a switch, and connect by another wire the other terminal of the switch to the other terminal of the battery, first placing the switch in the open position. Then insert a small iron bar or a bundle of iron wires in the cylinder and switch on, and it will be found that the iron has become magnetized, and will attract another piece of iron, although no current has passed through it. Upon switching off the current it will be demagnetised.

Now construct another coil of such a size that it will fit outside the first cylinder, using very fine insulated wire and a much larger number of turns, place it outside the first coil (known as the primary coil), hold the two ends in your hands and switch on again. At the moment of switching on, the current in the coil connected to the battery will cause another current of higher voltage to flow in the outer or secondary coil, and if you have made a sufficient number of turns of wire in the secondary coil, you will feel a distinct shock, which will be repeated every time you switch on and off. If by some

means such as the vibrator of an electric bell you cause rapid making and breaking of the primary circuit, you will receive a succession of shocks following so rapidly upon each other that you will think it is continuous. *The current set up in the secondary coil is called an induced current*, the act of producing it is called induction and such a coil is an induction coil.

Conversely, if a magnet be pushed into and out of a coil of wire, it will set up a momentary electric current in the coil every time it is moved in and out. This can be proved by connecting the ends of the coil wire to a galvanometer instead of to a battery. Exactly the same thing happens if the coil is moved and the magnet is stationary. But if neither is moved no current flows, showing that it is only when the magnetic field is disturbed by the passage through it of the coil that current is produced.

Theoretically, the influence of a magnetic field extends to an indefinite distance, but the useful extent of its influence depends upon several things: notably the strength of the current producing it.

The flow of an electric current is Nature's method of restoring equilibrium when natural forces have been displaced. A dynamo does not create electricity and pump it along wires. What it does is to create what is known as a difference of potential between two points which are called the poles or the positive and negative terminals of the dynamo. On electrical instruments the positive terminal is usually denoted by the sign + and the negative by the sign -. If we connect the two poles or terminals of a working dynamo or battery

by a wire, electricity flows and restores equilibrium.

If in the wire connecting the positive and negative terminals of a dynamo or battery we interpose an electrical appliance, the current can be made to operate it.

THE VOLT is the unit of measurement of the pressure of an electric current. The difference of potential set up by a dynamo or by a battery is not the same in every case, but may vary enormously, and the pressure behind the resulting electric current varies accordingly.

THE AMPERE is the unit of measurement of the amount of current passing along a conductor.

THE OHM is the unit of measurement of the resistance offered to the flow of an electric current. Even the best conductors offer a certain amount of resistance to the current. If we allow an excessive current to flow through a wire, the wire becomes hot; if it offers a very high resistance it may even become red or white hot and fall to pieces.

The three terms *volt*, *ampere*, and *ohm*, although denoting different qualities, are interdependent. The power value of the current that flows along a conductor depends on the pressure (voltage), the amount (number of amperes), and the resistance (measured in ohms) of the conductor. Knowing these we can calculate the *power* value of the current which is denoted in watts, 746 watts being equal to 1 horse-power and 746 watts of current for one hour being equal to 1 horse-power for one hour. A kilowatt is equal to 1,000 watts. The following simple equations show how, given

any two of the three things—volts, amperes, and ohms—we can find the third.

$$\text{Number of amperes} = \frac{\text{number of volts}}{\text{number of ohms}}$$

$$\text{Number of ohms} = \frac{\text{number of volts}}{\text{number of amperes}}$$

$$\text{Number of volts} = \frac{\text{number of amperes} \times \text{number of ohms}}{1}$$

Also :

$$\text{Number of watts} = \frac{\text{number of amperes} \times \text{number of volts}}{1}$$

$$\text{Number of kilowatts} = \frac{\text{number of amperes} \times \text{number of volts}}{1000}$$

To make this quite clear let us apply the equations in the case of a current of 10 amperes and 100 volts.

Then :

$$\text{Number of ohms} = \frac{100}{10} = 10$$

$$\text{Number of watts} = 10 \times 100 = 1000$$

$$\text{Number of kilowatts} = \frac{10 \times 100}{1000} = 1$$

When a dynamo is at work it does not produce a perfectly continuous difference of potential. It creates differences that follow each other very rapidly. Consequently the flow of current is not absolutely continuous, but consists of a series of impulses, so close that for practical purposes we may regard them as continuous. These impulses all travel in the same

direction, and the current is known as "continuous" or *Direct Current* (D.C.). The current from primary cells and accumulators is, of course, direct current.

Alternating Current (A.C.) is a type of electric current in which the impulses do not all travel in the same direction, but alternately in opposite directions. This alternation is due to the differences of potential being produced, so that they act first in one direction and then in the opposite direction, with the consequence that the direction of each current impulse is opposite to that of the one before and after it. It is generated by a machine called an alternator to distinguish it from a dynamo, which generates direct current.

Both alternating and direct current can be generated at different pressures. In the case of alternating current, it can also be generated at different speeds of alternation called the periodicity or frequency. For instance, when used for lighting or power purposes the average frequency is 60 changes of direction per second.

Now a word about *condensers*. In its simplest form a condenser consists of two parallel metal plates, separated by a "dielectric" consisting of air, mica, waxed paper, or some other suitable insulating substance.

If the plates of the condenser are connected to the positive and negative terminals respectively of, say, a cell or battery, one of the condenser plates becomes positively charged (i.e., has a deficit of "electrons," which may be regarded as negative particles of electricity), while the other plate becomes negatively charged (i.e., has a surplus of electrons).

This potential difference remains after the condenser is disconnected from the source of supply; in other words, the condenser is a device that is capable of storing up a charge of electricity. (The charge leaks away eventually, but an efficient condenser holds its charge for a considerable time.) If a wire from one plate of the charged condenser is brought near enough to the other plate, a discharge of electricity takes place through the air across the gap. But air, being a non-conductor, offers so much resistance that it becomes hot, and so the charge of electricity appears as a spark or streak of light. The greater the difference of potential or pressure the greater the distance the spark will leap through the air. The discharging of the condenser restores the equilibrium so that a difference of potential no longer exists.

The *capacity* of a condenser means the extent to which it can be charged with electricity. The larger the effective (or overlapping) area of the metal plates, and the closer they are together, the greater the capacity of the condenser. What is known as the "*specific inductive capacity*" of the dielectric also affects the capacity; thus the capacity of a given air-spaced condenser can be increased by substituting mica in place of the air dielectric.

The capacity of condensers used for wireless purposes is measured in MICROFARADS, one microfarad (mfd.) being a millionth part of a farad, which is the unit of measurement of electrical capacity.

We now come to a simple principle of electricity and magnetism which has a most im-

portant bearing on the working of wireless apparatus: it is that *like* poles of a magnet repel one another, while *unlike* poles have a mutual attraction for one another. That is to say, the N pole of one magnet attracts, and is attracted to, the S pole of another magnet, whereas the N pole of one magnet repels, and is repelled by, the N pole of another magnet, and so on.

The same thing applies to charges of electricity. Like charges tend to repel one another, unlike charges have a mutual attraction for one another. In the operation of a radio valve, for instance, a stream of negative electrons emitted from the filament is attracted to the anode or plate because the latter has a high *positive* potential applied to it by means of a battery. If the plate were charged negatively instead of positively, the stream of electrons would be repelled instead of attracted to it.

CHAPTER II

WIRELESS WAVES

ELECTRO-MAGNETIC (or "wireless") waves form the invisible link between transmitting and receiving stations. They are the essential basis of all radio communication, and they may be regarded as pulsations or disturbances in the ether of space.

Once upon a time it was supposed that, beyond the film of air surrounding the world, space consisted of a boundless vacuum through which the sun's light and heat poured down to the earth in a kind of shower; but, since scientists began to examine more carefully the reason of things, they have come to the conclusion that, in order that the sun's light and heat may reach the world, some kind of medium is necessary.

A medium simply means something by means of which something else can take place. Thus water is the medium by means of which sea-waves travel. A medium was therefore assumed for the conveyance of the sun's rays, and called "æther" or "ether." The ether is supposed to possess some very extraordinary properties which are a little difficult to grasp. Although invisible and transparent, it is supposed to be more than a million times denser than steel, to penetrate and permeate all matter, and yet not to hinder the passage of suns and worlds through it.

Fortunately for mankind, science progresses by leaps and bounds; at the same time, this fact involves the reconsideration, from time to time, of scientific theories which have been firmly implanted in the mind of the amateur—in this case I refer more particularly to the wireless amateur. The theory of relativity has led to considerable doubt in the minds of a good many scientists as to whether there is such a thing as the ether. On the other hand, there are still many who contend that it is impossible to explain such mysteries as wireless phenomena without the assistance of a hypothetical ether, which has served and still serves (even though it may be on an incorrect assumption) to explain the propagation and reception of wireless waves. Whatever may be the outcome of the new theory, for the present, the wireless amateur need not greatly concern himself as to whether wireless waves are dependent upon such a medium or not, and it would be inappropriate, at the present moment, to do more than mention the fact that there is a well-founded doubt about the whole subject.

All matter, whether metals, rocks, liquids, or gases, consists of minute particles called molecules, far too small to be seen by the most powerful microscope. These molecules in turn consist of atoms, and atoms of electrons, so that when we get down to the electron we are near the basis of everything of the existence of which we are conscious.

We know quite well that sound is a sensation produced by air waves travelling at 1,100 feet a second impinging upon the ear drum and

producing vibrations which are conveyed to the brain by auditory nerves.

It is now believed that light and heat proceed from the sun through the ether as waves travelling at a speed of 186,000 miles a second, which is the proved speed of light. Light waves are reflected by objects to our eyes, on the retina of which images are produced and conveyed to the brain by the optic nerves, where they produce the sensation of light, colour, and form. Heat waves, which are invisible, produce a different sensation—namely, that of heat. It is not that the waves themselves are hot, for they can pass through many feet of ice-cold water, and even then, if focused by a magnifying glass, will set fire to an inflammable substance.

But light and heat waves are not the only kinds of ether waves—there are many others. One of these is electro-magnetic waves which all travel at the same speed, but vary greatly in length.

Let us consider now the nature of these waves, beginning with the usual illustration.

If we drop a pebble into a pool of still water we set up ripples which are waves of energy, and which travel in ever widening concentric circles away from the point of disturbance. As they extend they become weaker and weaker. Whilst they are still there, drop another, much larger stone, which will make a greater disturbance than the first. On the surface of the pond you will then have two different sizes of waves overlapping each other, one kind being longer than the other, from crest to crest. You might keep on dropping stones in this manner, and you would see that the waves cross each other.

It is very important to remember that the water does not travel along ; it only moves up and down. It is only the waves that travel.

Of course, these are only surface waves. But supposing that at half the depth of the ocean we were to explode a charge of dynamite : the disturbance would set up waves that would travel outwards from the point of the explosion, like expanding globes instead of circles. And they would not be quite the same kind of wave. It is more or less in this manner that light waves proceed from the sun in every direction, and you may compare, if you choose, waves from the sun with the skins of soap bubbles one within the other, almost touching each other and joined together, and always expanding to an indefinite size. Our little world catches only the very minutest fraction of each wave. If the skins were some distance apart but still joined together, they would correspond to electro-magnetic waves.

Now the electro-magnetic waves which we produce in the ether for wireless purposes possess the same essential properties as those that reach us from the sun, but there are certain important differences.

Aerials consist of wires leading up masts and stretching across to other masts. Into these wires a rapidly oscillating electric current is allowed to flow. The wires and the earth correspond to the two plates of a condenser (described in the last chapter), and the intervening air or ether constitutes the dielectric. Every time the current speeds into the aerial and out again, it produces a strain or pulsation in the ether between the wires and the earth ; in other

words, it sets up in it an electro-magnetic wave. All the waves set off at a speed of 186,000 miles a second, their strength depending upon the strength of the electric current producing them, and other factors. Their length from crest to crest varies according to other considerations—it would be possible to set up about 1,000,000 different wave lengths which could be distinguished from each other. But, unlike light waves, these electro-magnetic waves do not travel in straight lines. They spread out, it is true, but they follow the curvature of the earth.

The reason for this was a puzzle for a time, until at last a theory was evolved, which apparently offers a satisfactory explanation, and which such eminent scientists as Dr. J. A. Fleming (the inventor of the thermionic valve) uphold.

It is well known that tremendous upheavals take place in the sun's glowing mass. Tongues and jets of flame hundreds of thousands of miles in length shoot out, when eruptions occur, and far beyond these flames immense quantities of dark gases are projected into space. Probably the bulk of these fall back again to the sun, but it is thought that much finds its way beyond the orbit of the earth, and that large quantities of this "dust" become entangled in the earth's atmosphere. Of course, we must not think of this as ordinary dust; it may be of an atomic character, and too fine to penetrate the lower and heavier part of the air. It is supposed that this "dust" is ionised or electrified, and that it acts as a screen round the world, and prevents our electro-magnetic waves from escaping; that when they encounter this

screen, they are reflected or deflected by it, and compelled to travel round the world.

When a wireless station is transmitting, high-frequency currents oscillating through the aerial system set up electro-magnetic waves which are radiated outwards in all directions from the transmitting aerial, and these waves fleet through space with the speed of light.

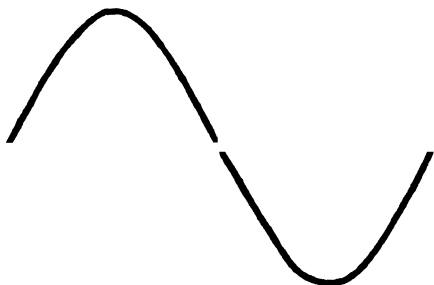


Fig 1

Now, measurements of wireless waves can be expressed in terms of length or frequency. *Wavelengths* are generally expressed in metres, and *frequencies* in kilocycles per second. One kilocycle, of course, equals one thousand cycles, and one megacycle (a term sometimes used when dealing with very high frequencies) equals one million cycles.

There is a definite relation between the speed, length, and frequency of wireless waves. The velocity remains constant at (approximately)

300,000 kilometres (or 186,000 miles) per second, while the frequency varies inversely with the length, as may be seen from the following comparisons between certain wavelengths and their equivalent frequencies :

30,000 metres		10 kilocycles per second		
3,000	"	100	"	" "
300	"	1,000	"	" "
30	"	10,000	"	" "
3	"	100,000	"	" "

Given the frequency of a station, one can find the corresponding wavelength by dividing 300,000 (the velocity in kilometres) by the frequency in kilocycles per second. Or, given the wavelength, one can find the equivalent frequency by dividing 300,000 by the wavelength in metres.

That, of course, is just simple arithmetic—but what do we mean by the terms “wavelength” and “frequency”? Well, we can represent on paper the mathematical features of a wireless wave by means of a curve like that shown in Fig. 1. This curve represents one complete wave or cycle; a train or succession of uniform waves could be represented by repeating the curve a number of times.

The number of complete cycles or waves which occur per second constitutes the frequency, while the wavelength is a measurement of the distance from a given point on a curve representing one wave to a corresponding point on an adjacent curve representing the next wave in the train. For example, one could measure the wavelength from the crest of one wave to

the crest of the next, or from the trough of one wave to the trough of the next, and so on. The amplitude of the wave is represented by the vertical height of the half-wave above, or vertical depth below, the horizontal line which represents time.

CHAPTER III

THREE-ELECTRODE RADIO VALVES

It is impossible to over-estimate the stupendous effect of the thermionic valve on the development of radio communication. Broadcasting, and in fact all forms of wireless telephony, as well as present-day methods of morse signalling, owe their very existence to the invention of this marvellous device.

Without the thermionic valve (or some equally effective substitute, so far undiscovered), radio communication would be confined within the narrow limitations imposed by the use of crude, old-fashioned apparatus, such as spark transmitters and crystal receiving sets.

For the invention of the radio valve the world is indebted, in the first place, to Dr. J. A. Fleming.

Whilst experimenting with ordinary incandescent electric lamps, Dr. Fleming came to the conclusion that when the filament is glowing an invisible something is shot off from it. That something we call electrons—"the stuff electricity is made of." Dr. Fleming then had some lamps made, in each of which there was a small metal plate with a separate terminal, and discovered that with a certain arrangement of batteries and by coupling up the terminals in a certain manner, and then applying an alternating current to the valve, only the impulses in one direction could pass, those in the other

direction being stopped, much as the valve of an inner tube of a bicycle or motor car will only allow air to pass through it in one direction. His invention, therefore, came to be known as the "Fleming valve," and one of the first uses it was put to was to rectify alternating current from wireless aërials, and render it suitable for use in the telephone. In this respect the valve serves the same purpose as a crystal.

Later on, Mr. Lee de Forest made an improvement, which consisted of introducing a piece of metal gauze or a coil of fine wire between the ordinary filament and the plate. This was attached to a separate terminal, and from this the modern three-electrode valve was developed. Although valves have been improved enormously in design, efficiency, and performance since the early types were first put on the market, the essential features of the three-electrode valve remain substantially the same.

Briefly, a three-electrode valve consists of a glass bulb mounted on an insulating base; inside the glass bulb, which is almost completely exhausted of air, are mounted the three electrodes, known as the *filament*, *grid*, and *anode* (or *plate*) respectively. *The order in which the electrodes are placed is always the same*, irrespective of the make or type of valve: the anode surrounds the grid, and the grid in turn surrounds the filament, so that electrons emitted from the heated filament have to pass between the meshes of the grid before they can reach the anode. This particular disposition of the electrodes is essential to the working of the valve, as you will see later.

The anode, grid, and the two ends of the

filament are connected to wires which pass out through the bottom of the glass bulb and are connected in turn to four metal legs or spigots protruding from the lower surface of the insulating valve-base. These connexions, together with the arrangement of the electrodes, are shown in a simple diagrammatic form in Fig. 2.

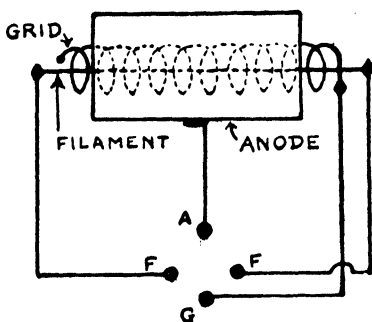


Fig.

The four metal legs on the valve-base are arranged to plug into corresponding sockets in a valve-holder mounted on the baseboard or chassis of the receiving set. The valve sockets are wired up to batteries and other parts of the receiving apparatus.

There are many different types and makes of receiving valves, and the form of the electrodes, used, as well as the method of mounting them, varies rather widely with the different kinds. The simplest arrangement (such as was used in the early types of three-electrode valves)

consists of a cylindrical anode, spiral wire grid, and straight filament. It is usual to denote the valve diagrammatically as in Fig. 3, in which F represents the filament, G the grid, and A the anode.

It is important to remember that, whilst the filament has both an entering and a return lead, the grid and anode have only one lead each ; and *that there is no connexion whatever inside the valve between the filament, the grid, and the anode.* The ends of the filament leads are connected

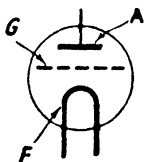


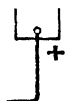
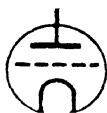
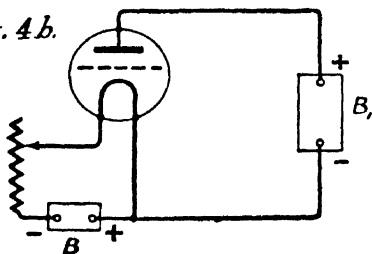
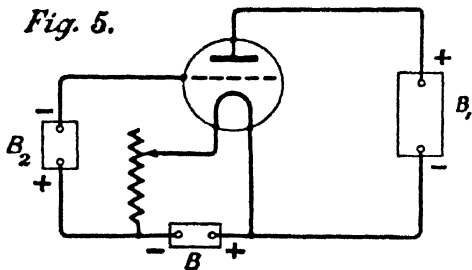
Fig. 3.

to the terminals of an *accumulator* or low-tension battery (2, 4, or 6 volts, according to the type of valve) in series with a switch. When the switch is closed, so as to complete the circuit, current flows through the filament and heats it considerably. The filament is composed of specially treated wire which, when heated to a certain temperature, by the passage through it of an electric current, is capable of emitting a copious stream of *electrons* from its surface. Free electrons are the smallest conceivable particles charged with negative electricity—in fact we may think of them as negative particles of electricity. As already explained in the

chapter on Electricity and Magnetism, like charges of electricity mutually repel, but unlike charges mutually attract one another; i.e. a positive charge attracts a negative charge, and vice versa.

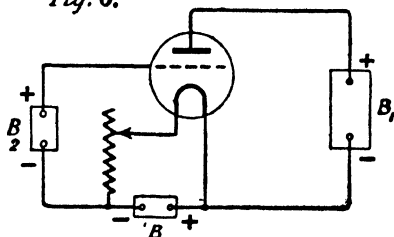
If, therefore, in the anode circuit of a valve we interpose a 30-volt battery, B_1 (Fig. 4a), connecting the anode to the negative terminal, it will oppose the flow of electrons from the heated filament to the anode. If, however, we connect the anode to the positive terminal of the battery, B_1 (Fig. 4b), the stream of electrons will be attracted to the anode. Not only so, but the cloud of electrons between the anode and filament pave the way, so to speak, and prepare a conducting path, so that a comparatively strong flow of current takes place from the battery through the valve from the filament to the anode, the ultimate strength of this anode current depending on the number of electrons that escape from the filament.

Let us next turn to the grid. Suppose that the filament is glowing, and that a current is flowing in the anode circuit. Now let us introduce a *grid-bias* battery, B_2 , of, say, 6 volts (Fig. 5), with its negative terminal connected to the grid, and its positive terminal to the filament. We now have a third circuit, with a gap in it between the filament and the grid. If we switch on the grid battery no appreciable current will flow in the grid circuit, but a charge of electrons from the grid battery will crowd on to the grid, and since all electrons are negative, this charge on the grid will have the effect of repelling the flow of electrons from the filament to the anode, thereby cutting off the current in

Fig. 4 a.*Fig. 4 b.**Fig. 5.*

the anode circuit. Thus a battery potential on the grid will stop an anode current of many times its own voltage. Moreover, it makes no difference whether the anode battery is capable of delivering half an ampere or 200 amperes : it cannot send current through the valve unless the voltage is many times that of the grid battery. The anode voltage, which can be controlled by the grid voltage, depends upon the

Fig. 6.



design of the valve ; a valve could be constructed in which the grid could control a current in the anode circuit of a hundred times its own voltage.

If, on the other hand, we reverse the connexions of the grid battery by connecting its positive terminal to the grid (Fig. 6), more current will flow through the valve from the anode battery than if there were no grid battery at all.

It is clear then that the flow of a strong current in the anode circuit can be controlled

simply by applying a comparatively small potential to the grid, and that by varying the voltage of the grid potential we can either stop the anode current altogether, or cause it to fluctuate in intensity. No matter how rapidly the voltage of the grid potential is changed from positive to negative and vice versa, every change produces an instant effect upon the anode current. If therefore, instead of applying a battery potential to the grid, we connect the grid by a wire to an aerial circuit, every positive impulse of current from the aerial will tend to increase the flow of anode current, and every negative impulse of aerial current will tend to reduce or to stop the flow of anode current. If (as will be described later) things are so arranged that every negative impulse causes a very small reduction in the anode current, whilst every positive impulse causes a comparatively large increase in the anode current, the valve is acting as a rectifier. But if matters are arranged so that every negative impulse causes a reduction in anode current as great as the increase caused by every positive impulse then the valve is acting as a high-frequency amplifier, in that it enables the low-voltage alternating current from the aerial to impress its oscillations in exact proportion upon a high-voltage current flowing from the battery in the anode circuit. The difference between rectification and amplification will be better understood after reading the chapter on characteristic valve curves.

CHAPTER IV

CHARACTERISTIC VALVE CURVES—AMPLIFICATION AND RECTIFICATION

ALTHOUGH it must be admitted that valve-curve diagrams are at first sight somewhat forbidding to those unaccustomed to them, they are really quite easy to understand.

Fig. 7 is a "characteristic curve" of a Mullard valve specially designed as a detector. On the horizontal base line volts are measured off on each side of a point marked O. Those on the right of this point are positive volts, and those on the left negative volts. These volts represent different potentials, or electrical pressures, which may be applied to the grid of the valve. The vertical line on the right-hand side of the diagram is divided into spaces representing milliamperes of current which flow through the valve from the filament to the anode. (Although there is no connexion between the filament and anode inside the valve, the circuit is completed by virtue of the invisible stream of electrons emitted by the filament and attracted to the anode.) This current, known as the anode current, is supplied by the high-tension battery in the anode circuit of the valve.

The curve marked 50 volts, which begins as a curve on the left of the diagram and develops into a steep, straight line, is the characteristic curve for an anode voltage of 50, while the other curve is for an anode voltage of 20.

Let us suppose that the filament battery is switched on, and that the high-tension battery

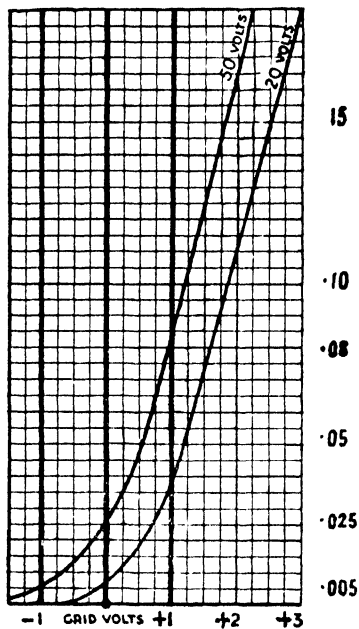


FIG. 7

in the anode circuit is arranged so as to apply a positive potential of 50 volts to the anode. At this stage there is no negative or positive

potential on the grid, which is therefore in a condition corresponding to the point O on the "grid volts" line in the diagram. Following the vertical line from this point to where it cuts the curve corresponding to an anode voltage of 50, and then following the horizontal line, we get a reading of .025 milliamperes, which means that a steady current of .025 ma. (milliamps.) is flowing through the anode circuit of the valve.

Now, if by means of a small battery (termed the grid-bias battery) and a potentiometer, we apply a positive potential of one volt to the grid, we should take our reading from a horizontal line drawn from a point where the vertical line from +1 cuts the curve. This shows that the effect of applying a positive bias of one volt to the grid is to increase the anode current to .085 milliamperes.

If, on the other hand, we reverse the grid potential, by connecting the negative terminal of the grid battery to the grid, we find that the anode current is reduced to .005 milliamps.

It amounts then to this: that a positive grid potential of 1 volt increases the normal anode current by .06 milliamps., whereas the application of a negative pressure of 1 volt only decreases it by .02 milliamps.

Supposing now that we disconnect the grid battery entirely, and connect the grid to an aerial circuit which is being swept by carrier waves only, so that the alternating aerial current acts upon the grid; and imagine that the aerial current imposes an alternating pressure varying from +1 to -1 volts on the grid. Then we should obtain the same readings

as before, each positive impulse causing a much larger increase in current than the decrease caused by each negative impulse. That is the principle underlying rectification, i.e. to obtain a larger increase than decrease of anode current, and there is a critical point on the curve at which the maximum difference can be secured, so that the current from the aerial swings the alternating potential equally on each side of this critical point. The valve is then rectifying. This, however, is only part of the story.

Suppose, now, that audio-frequency signals begin to arrive. These are merged in the H.F. alternations, their effect being to vary the amplitude of the H.F. oscillations, so that if the aerial current—signals and all—were passed directly to the telephone, nothing would be heard, even though the aerial were properly tuned, partly because the telephone receiver windings would prevent the passage of H.F. currents, and partly because the diaphragm of the receiver could not respond to oscillations of the order of a million per second: the diaphragm would in fact remain stationary. But if, as already described, the aerial current impulses are applied to the grid of the valve, the unidirectional spurts of anode current are modulated by the audio-frequency variations, causing a low-frequency fluctuation in the strength of the anode current; consequently, if the anode current be passed through the headphone receiver, the diaphragm will respond to the L.F. fluctuations and reproduce the original sound waves. If we take readings on the 20-volt curve we see that -1 volt would practically cut off the anode current entirely.

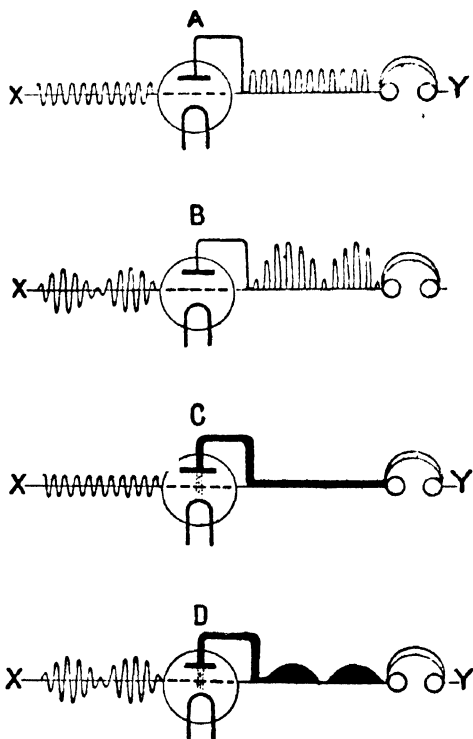


Fig. 8.

Valves vary considerably in design. If the critical point on the characteristic curve corresponds to an initial potential on the grid of sufficient voltage just to prevent the flow of anode current, then every positive impulse would open the valve and allow a little burst of anode current to pass, whilst every negative aerial impulse would close the valve even more effectually, with the result that the spurts of anode current would each pass separately through the valve.

Fig. 8A illustrates a case in which the anode current is completely cut off except when a positive impulse acts on the grid. Fig. 8B shows the rise and fall in amplitude of aerial current, and of the rectified current, caused by L.F. signals. On the right-hand side of the valve (Fig. 8A) the separate spurts of current are shown as half-curves, but these spurts follow each other so rapidly (about a million a second) that by the time they get into the telephone windings they have merged into a continuous stream. Fig. 8A may therefore be substituted by Fig. 8C, in which the thick line between the valve and the telephones represents the rectified current of uniform amplitude due to carrier waves only. And Fig. 8B may be substituted by Fig. 8D, in which the thick dark line on the right of the valve indicates variations in the anode current due to low-frequency signals.

Figs. 9A, B, and C, illustrate a case in which the anode current fluctuates between a minimum and a maximum. In Fig 9A the effect of the aerial oscillations is shown as uniform ripples on an initial, steady anode current. Fig. 9B shows the modulations due to audio-

frequency signals, and Fig. 9c the mean rise and fall of the anode current.

It remains to consider the limits within which a valve can be made to rectify. Reference to Fig. 7 (the characteristic curves) will make it clear that the greater the variation in the aerial current applied to the grid, the greater will be the variation in amplitude of the anode current, and therefore the greater the extent to which the telephone diaphragm will deflect, and the louder the sounds the diaphragm will produce. If the aerial currents are very feeble indeed it is easy to see from Fig. 7 that the valve cannot rectify them, since the decrease in anode current, due to a negative impulse on the grid, will be practically equal to the increase due to a positive impulse. The consequence of this is that an unidirectional oscillating current would flow in the anode circuit, and since this current would only vary at high-frequency, its mean value would remain the same, and it would produce no sounds in the telephone receivers.

On the other hand, suppose that the aerial current has been amplified to such an extent that it is unduly strong : then the alternating potential it imposes on the grid would swing too far on each side of the critical point on the curve, energy would be wasted and distortion of signals would result, while no advantage would be gained.

The best and most popular way of applying the three-electrode valve to the purpose of rectification is that known as the grid condenser and leak method. Instead of applying the aerial currents directly to the grid, a condenser

is inserted in the circuit, and from a point between this condenser and the grid a wire leads to a high resistance known as a "grid leak." The return end of the grid leak is

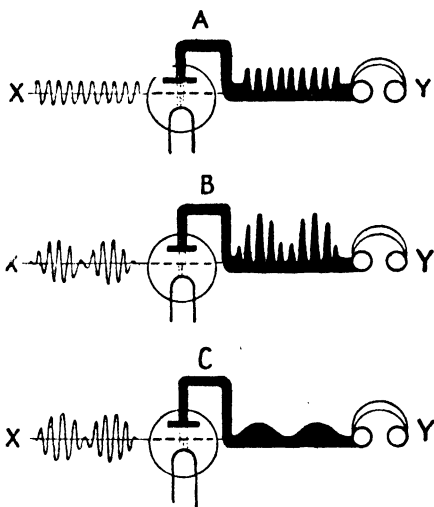


Fig. 9.

usually connected to the positive terminal of the filament battery, but an alternative arrangement is to shunt the resistance across the grid condenser as shown in Fig. 10. This is really equivalent to connecting the end of the grid

leak to L.T. negative via the inductance coil. An even better plan is to connect the end of the grid leak to the moving contact-arm of a fairly high-resistance potentiometer shunted across the low-tension battery.

Readers who are familiar with the characteristic curve of a crystal detector, will readily perceive a similarity between such a curve and that of a rectifying valve. Within certain

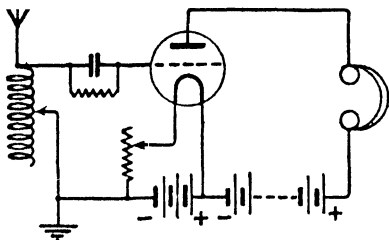


Fig. 10.

ranges of applied potential, neither the crystal nor the valve follows Ohm's law. According to that law, the resistance of a given conductor remains constant under ordinary conditions, so that the formula : $\text{amperes} = \frac{\text{volts}}{\text{ohms}}$ holds good, and the amperes are directly proportional to the volts. In the case of a valve detector, however, this law only holds good above a certain voltage where we are on the straight portion of the characteristic curve. At the critical point

on the curve, an increase of positive grid potential allows a greater increase in anode current than the decrease due to a reduction in grid potential of exactly the same amount.

When a high-frequency current flows through a valve, it has to overcome what is termed the "impedance" of the valve; impedance being the sum total of all factors, including resistance and reactance, which oppose its flow. Impedance is therefore an important factor to be taken into consideration in the design of valves and their effective amplifying power.

The impedance of a valve depends on the rate at which the anode current varies according to the anode voltage. Referring to the curve (Fig. 11) of a Mullard amplifying valve, and reading upwards from the point of O grid potential, it will be found that with an anode voltage of 30, a current of about .5 milliamp. flows in the anode circuit. Taking a corresponding reading with an anode voltage of 90, the reading is about 2.5 milliamps. Thus, by increasing the anode voltage by 60, we secure an increase in current of about 2 milliamps. Dividing the change in voltage by the corresponding change in amperes, and multiplying by 1,000, we obtain approximately the impedance of the valve in ohms. In the case in point it is $\frac{60}{2} \times 1,000 = 30,000$ ohms. It is necessary to

multiply by 1,000 because there are 1,000 milliamperes in one ampere.

Let us now consider how the valve can be made to function as a high-frequency amplifier.

Referring to Fig. 11, if we follow the vertical line from the point marked O volts, it will be

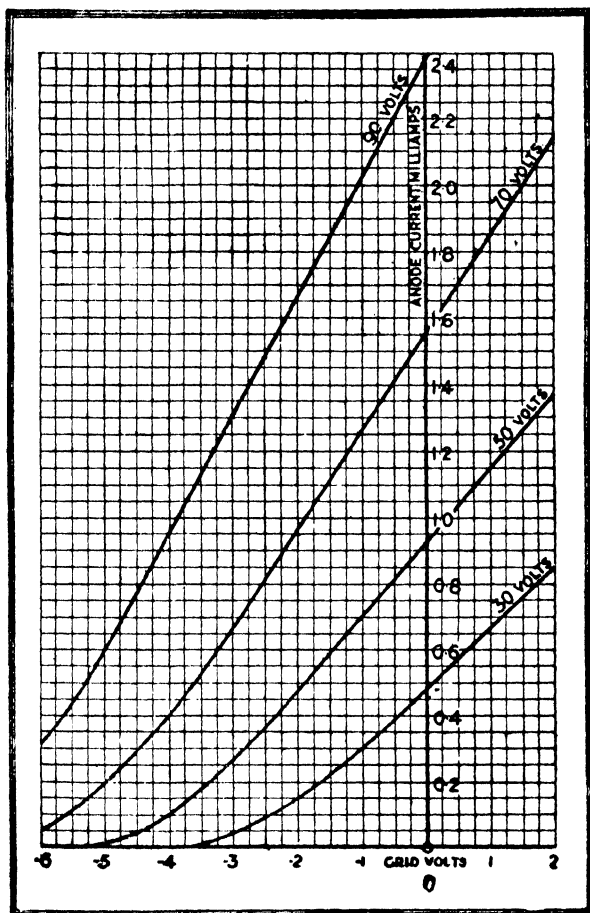


FIG. II

found to cut the steep, "straight" portion of each curve at such a point that there will be an appreciable length of the straight portion on either side of the intersection.

Suppose now that we have tuned in to weak signals and that the grid is coupled up to the aerial circuit as before, but that no initial voltage is applied, and imagine that the swings of aerial current impose a potential on the grid varying from $+\frac{1}{4}$ to $-\frac{1}{4}$ volt. Following the vertical lines from the two points corresponding to $+\frac{1}{4}$ and $-\frac{1}{4}$ grid volts to where they intersect any of the curves, and reading off the anode current indicated by the corresponding horizontal lines drawn from the points of intersection, it will be found that a negative impulse of $\frac{1}{4}$ volt produces as great a reduction in the flow of the anode current as the increase caused by a positive pressure of $\frac{1}{4}$ volt. In other words, the valve is not rectifying: it is causing evenly balanced oscillations in the anode current. Not only so, but the feeble alternating grid potentials are controlling the flow of a comparatively heavy current of much higher voltage in the anode circuit. Thus the valve is acting as an amplifier of high-frequency currents. It will be noticed that the negative impulses do not embrace the curved portion of the characteristic curve. In practice, most valves intended for H.F. amplification are so designed that they operate efficiently as H.F. amplifiers without any initial potential being applied to the grid.

Fig. 12 illustrates the effect of the grid potential upon the otherwise steady flow of anode current through the valve: A represents the H.F. oscillations in the anode current caused

by carrier waves, and B the variations caused by L.F. signals. For reasons already explained, the current thus produced has then to be rectified before it can operate the headphones or loud-speaker.

It sometimes happens, even when the aerial current has been amplified, that it is still too

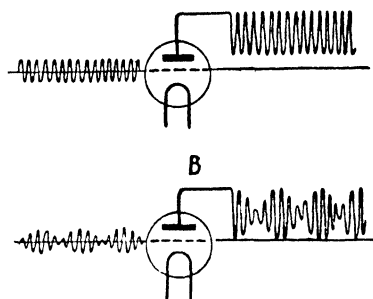


Fig. 12.

weak for rectification. It may then be passed through the primary coil of a transformer, in the secondary coil of which it will produce a high frequency alternating current, which is then applied to the grid of a second amplifying valve. After this second amplification, the current may be rectified and passed through the telephone receiver.

A third function of the valve in wireless reception is to magnify the low- or audio-frequency variations in the current after it has been rectified. Fig. 13 will help to make this clear. R is a valve detector, T a transformer, L a low-frequency magnifying valve, and *t* the telephone receiver. From A to R is the H.F. alternating current modulated by audio-frequency signals; this is rectified by the valve R, and from R to T we have L.F. unidirectional current. This is converted by an iron-core transformer, T, into a low-frequency alternating current acting upon the grid of the low-frequency magnifying valve, L, which magnifies the low-frequency current variations and passes them on to the telephone receiver, *t*.

A transformer of the iron-core type is more efficient than an air-core transformer for low-frequency currents.

CHAPTER V

INTERVALVE COUPLING DEVICES

WHEN we say that a valve amplifies wireless signals, we really mean that the fluctuating signal currents applied to the grid circuit of the valve cause corresponding fluctuations on a much larger scale in the current that flows through the anode circuit. This latter current is, of course, derived from a purely local source—namely the H.T. battery or, in the case of a mains set, the electric light supply.

In every set containing several valves the amplified output from the anode circuit of each valve has to be passed on to the grid circuit of the next valve, in order that the signals may be rectified, or still further amplified, or both, as the case may be. Some sort of coupling device is therefore required between every two adjacent valves in a set, to pass on the signal output from the anode circuit of one valve to the grid circuit of the following one.

Whatever coupling device is employed, it has to serve more than one purpose. It has not merely to pass on the amplified signals to the valve that follows it, but has also to isolate the grid of that valve from the direct high-tension battery current flowing in the anode circuit of the preceding valve. The coupling device may even perform a third function: it may step up the signal voltages to a much more effective value, thus increasing the overall amplification

of the complete valve stage to an enormous extent.

A transformer is an example of a coupling device that is capable of "boosting up" the signals before passing them on to a following valve. Transformers, chiefly for that reason, provide one of the most popular means of coupling, especially in the case of L.F. stages. H.F. and L.F. transformers differ widely from one another in construction, but the principle on which they work is much the same.

Let us see, therefore, how a transformer functions.

If two wires be laid parallel and close enough together, but without touching one another, and a current of electricity be sent through one of them, at the moment of starting it will produce another—momentary—current in the other wire, but in the opposite direction. The reason for this is as follows :

When an electric current begins to flow along a wire, it sets up lines of magnetic force round it. It is supposed that these lines of force act in a circular direction round the wire, the lines expanding until they become so weak as to produce no perceptible effect. With the current flowing towards one, could these magnetic lines be seen they would appear as concentric circles acting in a direction opposite to that of the hands of a clock. If the current were flowing in the other direction, the lines of force would appear to act in the opposite direction. The lines would appear to be most densely crowded close to the wire, becoming weaker and weaker as they expand away from it.

When a current begins to flow, it takes time

to do so at full strength, owing to its inertia, and when the difference of potential which causes it to flow is reversed, the current does not instantly stop and reverse, owing to its momentum. It is true that it only requires an extremely small fraction of a second to flow at full strength, and to stop and to reverse ; nevertheless it does take time. This inertia and momentum, which may be compared with that of solid bodies, is known as inductance,* and may be ascribed to two things : (1) the actual inertia and momentum of the electrons which constitute an electric current, and (2) the fact that as the current grows it has to build up the magnetic lines of force round the conductor, to stop them when the difference of potential ceases, and to build them up again when the potential difference is reversed. Inductance is chiefly due to these changes in the magnetic field. Even in the case of a unidirectional current which varies in amplitude, there is inductance, because, in growing and decreasing in strength, the flow of electrons has to reduce and build up the magnetic lines of force at every variation.

A unidirectional current which, at regular intervals, varies in amplitude, is known as an oscillating current. An alternating current also is an oscillating current, but it does not follow that an oscillating current is necessarily an alternating current.

If whilst the magnetic lines are growing they cut across another wire, they produce a dis-

* An explanation of inductance and capacity will be found in *Wireless Receiving Devices : Their Functions Simply Explained*.

turbing effect upon the electrons in the other wire, causing them to drift along it. Reverting to the case of the two wires side by side : when a current begins to flow in one of them, the magnetic lines of force sent out by it cut across the other wire, disturbing its electrons and causing a flow of current, until the magnetic field attains a definite range, when the induced current ceases. Any subsequent variation in the flow of current in the "live" wire causes a flow in the second wire, in one direction or the other.

If now, instead of laying two wires side by side, we were to wind a portion of the main circuit wire into the form of a coil, and a portion of the other wire into another coil, and place one coil within the other, the induction effect would be enhanced, because the lines of force, instead of being spread over a long length of wire, would be grouped together and assist each other, so that quite short coils would be sufficient for current variations in one of them to induce stronger currents in the other than in the case of the two parallel wires. Such an arrangement of coils is known as a transformer.

If we were to use insulated wire and wind the inner coil round a core or bundle of iron wires, and the outer coil round the inner coil, the iron core would serve to conduct the magnetic lines of force better than would an air space, with the consequence that the induction effect would be still further increased, and still stronger currents would be induced. Such a transformer is known as an iron core transformer.

In the case of an iron core transformer, the current takes longer to build up and pull back

the magnetic field, so that if the current variations were of sufficiently high frequency, there would be a choking effect, and such a coil would be less efficient than an air core transformer. For that reason, air core transformers are employed when dealing with high or radio-frequency currents of the order of hundreds of thousands or even millions per second; and iron core transformers are only employed in connexion with low- or audio-frequency currents up to about eight or ten thousand a second.

It should be borne in mind that the term "frequency" is applied equally to alternating and to unidirectional, oscillating currents.

It is clear then that the function of a transformer is to enable an electric current in one circuit (known as the *primary*) to induce an electric current in another circuit (known as the *secondary*).

The amount of energy induced in the secondary can never be greater than that in the primary—in fact it is invariably less, even in the case of the most efficient transformers. In other words, you cannot get more out of a transformer than you put into it. But a transformer can be so arranged that it transforms one variety of electrical energy, so to speak, into another variety that happens to be more effective for a particular purpose.

If the number of turns of wire in the two coils is the same, the induced current will be of the same voltage as that of the primary current; if the secondary coil contains say three times as many turns as the primary, the voltage of the induced current will be three times that of the current in the primary circuit :

in such a case the two coils constitute what is termed a step-up transformer. If, however, the secondary coil contains fewer turns of wire than the primary, the induced current will be of lower voltage than that in the primary, and the transformer is then of the step-down type. One might say that a step-up transformer increases voltage at the expense of current, while a step-down one increases current at the expense of voltage; a transformer cannot increase the total amount of power.

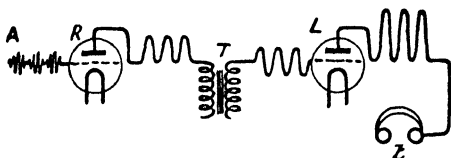


Fig. 13.

It should be explained that the foregoing voltage relations hold good irrespective of whether the transformer be of the air core or of the iron core type.

The pair of coils constituting a transformer can serve the double purpose of induction and of inductance coils. That is to say that they may be proportioned so as to give the required inductance in two circuits, and at the same time the primary may serve to induce a current in the secondary coil. H.F. transformers, when used in this way, may be tuned by means of variable condensers.

The L.F. transformers used for intervalve coupling have a step-up ratio of, say, 3 to 1, 4 to 1, 5 to 1, or even, in some cases, 7 to 1. The bigger ratios give greater amplification, but may tend to introduce distortion. The windings of an L.F. transformer are invariably fitted with a core and "surrounds" of iron (or a core made of special alloys) which serve to concentrate and conduct the magnetic lines of force between the two windings. The core of an L.F. transformer does not usually consist of a solid lump of metal, in which wasteful "eddy currents" would be set up, but is composed, instead, of many thin stampings or laminations, insulated from one another by, say, a thin film of paper on one side of each stamping.

To sum up, the following important facts should be borne in mind :

(1) a direct current of uniform amplitude passing through the primary coil of a transformer only induces a momentary current impulse in the secondary coil when the primary current starts or stops.

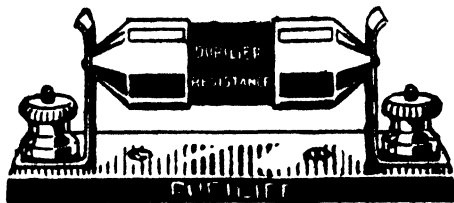
(2) An alternating current in the primary coil induces an alternating current of the same frequency in the secondary coil, but each impulse in the primary causes an impulse in the opposite direction in the secondary.

(3) A unidirectional oscillating current (i.e. a direct current of which the amplitude varies) induces a current impulse in the secondary coil every time the amplitude varies. As the current increases in the primary, it induces a current in the opposite direction in the secondary ; but as the current in the primary decreases, the

induced current is in the opposite direction to the first current impulse in the secondary.

(4) The voltage of the induced current differs from that of the primary in exact proportion to the number of turns of wire in the two coils.

Another popular method of linking up two adjacent valves is that known as resistance-capacity coupling, which depends for its working



on the insertion of a very high resistance (say, 50,000 ohms) in the anode circuit of the one valve, and a fixed condenser of suitable capacity to pass on the signals to the grid circuit of the next valve. A grid-leak of suitable resistance value is also required to complete the resistance-capacity coupling (or R.C.C.) unit.

The external appearance of a typical anode resistance is shown in Fig. 14, and to understand the use of this component one should know that, if a sufficiently high resistance be

inserted in the path of an oscillating current, the changes of direction of the current may be so rapid that, before a complete current impulse can force its way through the resistance, the direction of flow has changed, and the same condition obtains at every alternation of the current. The consequence is that, at every change of direction, the bulk of the electrons, unable to burst their way through the resistance, exert an electrical pressure between its two ends, this difference of potential changing from positive to negative and vice versa at every half alternation.

This changing voltage is applied by means of a fixed condenser to the grid of the valve following that which has the anode resistance in its plate circuit. The fixed condenser, one terminal of which is connected to the end of the anode resistance nearest the valve, serves the dual purpose of passing on the signal impulses and of insulating the grid circuit from the direct battery current that flows through the anode resistance.

In some cases a *choke coil* (an inductance containing a large number of turns of fine wire) is used in place of the anode resistance. An H.F. choke has no metal core, as this would be detrimental to results at high frequencies; but an L.F. choke is wound on a core resembling that of a transformer. In fact, the component is not at all unlike a transformer with the primary winding omitted.

Another form of intervalve coupling, frequently used in H.F. amplifiers, is that known as "tuned anode" coupling. An inductance coil, with a variable condenser shunted across

it, is connected in the anode circuit of the H.F. valve. This tuned circuit, when brought into resonance with the grid circuit of the H.F. valve by suitable adjustment of the variable condenser, acts as a kind of rejector, passing only the desired signals to the next valve.

CHAPTER VI

BROADCAST TRANSMISSION

BROADCASTING, or the transmission of wireless telephony, necessitates the radiation of a continuous and unbroken train of ether waves which can be modulated by means of sound waves, so that the slightest modulation or merging of the sound waves produces a corresponding effect upon the train of ether waves. These continuous ether waves are called "carrier waves."

We will first follow out the process of ordinary telephony from end to end.

A telephone transmitter comprises a little case in which there is loosely packed a small quantity of carbon granules, and through these granules an electric current from a battery flows. At one end the carbon granules bear against an extremely thin metallic plate or diaphragm fitted in the mouthpiece of the telephone. By lifting the receiver off the hook, we close an electric circuit and a current begins to flow steadily through the granules. But the moment we begin to speak, the sound waves of our voice impinging upon the diaphragm (which is exceedingly delicate and sensitive) cause it to vibrate and to press against the granules behind it with a force that varies exactly according to the modulations of the sound waves of our voice. Now, the flow of the current of electricity varies according to

how tightly the granules of carbon are packed ; consequently the varying pressure of the diaphragm upon the granules causes the flow of the current to vary accordingly.

The electric current passes along land wires to a receiver, which the person we are talking to holds to his ear. In this receiver there is a little electro-magnet energised by the current, and close to it a diaphragm which is attracted by the magnet. As the strength of the current varies, the diaphragm moves to and fro with varying force. With every such movement the diaphragm hits the air and reproduces exactly the original sound waves of our voice.

In the case of wireless telephony, we begin and end in the same way. But instead of the mouth-piece and ear-piece being connected by wire, the electric current, upon which the modulations representing sound waves have been impressed through the medium of the microphone, is caused to impart its modulations to high-frequency current pulsating through the aerial system. The oscillation of this powerful H.F. current sets up an unbroken train of carrier-waves, in the ether, which are in turn modulated in sympathy with the varying currents representing the original sound-waves. The modulated carrier-waves which travel outwards in all directions from the transmitting aerial of a broadcasting station may therefore be said to bear the imprint, so to speak, of the sounds produced before the microphone in the broadcasting studio.

The action of a simple carbon microphone, such as is used in ordinary line telephony, has already been explained. For broadcasting pur-

poses, much more sensitive and efficient microphones capable of responding to a far wider range of sounds, are required, and there are several different types in common use.

The original primitive type of carbon microphone has long been superseded by greatly improved models, those used at present by the B.B.C. being very sensitive, with an excellent "frequency characteristic," which means that they respond correctly to sounds of all frequencies from the very low notes of instruments such as the double-bass up to the very high notes of the violin or clarinet.

Another type of microphone which has been extensively used for broadcasting is that known as the magnetophone. This contains a coil of thin wire which acts as a diaphragm, suspended very delicately in a strong "magnetic field." As the sound waves impinge on the coil, they make it vibrate, and this minute movement sets up very weak electric currents in the coil, due to an electro-magnetic induction effect.

Yet another kind of microphone used for broadcasting purposes is the condenser microphone, so called because it contains two metal plates, very close together but not actually touching, that form a condenser. One of the plates is made of thin metal and acts as a diaphragm, which vibrates when the sound waves impinge upon it. The minute movements of the diaphragm cause variations in the capacity of the condenser, and these variations may be made to produce corresponding variations of current or voltage.

The B.B.C. engineers are constantly carrying out experiments with new and improved types

of microphone, working on the foregoing or other similar principles.

The microphone current passes to amplifiers, and the magnified version of it is dealt with in a "control room," which contains apparatus enabling the engineers in charge to control the strength and quality of the transmission. The apparatus in the control room includes volume controls which enable the output from the microphones in use to be correctly adjusted, and "mixer" controls for combining the output from two or more studios; as, for instance, in superimposing the "noises off" on transmissions of broadcast plays; arrangements for adding an artificial echo effect when necessary; controls for the S.B. lines used in "simultaneous broadcasting" and outside relaying; and so forth.

When, as often happens, the studio in which a broadcast performance takes place is a long way from the actual transmitting station, telephone lines (generally called "land lines" if they are of the overhead type, or "cables" when of the underground or undersea kinds) are used to convey the amplified microphone currents to the distant transmitter, where eventually they are made to modulate the steady carrier waves radiated from the transmitting aerial.

The majority of broadcasting stations use a method of modulation known as "choke-controlled modulation." There are two ways of modulating by this method: high-power and low-power. In the case of high-power modulation, the modulating valves control the full-power H.F. oscillations which are generated by the oscillating valves and applied to the trans-

mitting aerial. In the case of the low-power method, which has been adopted for the B.B.C. Regional stations, high-frequency oscillations are modulated at low power by the control valves which handle the amplified microphone currents, and are then magnified enormously by H.F. amplifiers, until they become strong enough to be applied to the aerial.

The valves used for transmitting purposes are not unlike receiving valves in general principle, but of course they are very much larger, and the power required to operate them is gigantic in comparison with that taken by receiving valves. The necessary power may be obtained from the public supply mains ; or it may be generated on the station premises, the latter method being usual in the case of big high-power stations.

Although, of course, the practical circuit of a powerful broadcast transmitter, such as a B.B.C. Regional station, is far too complicated to explain simply, we can form some idea of the principle on which it works if we take a greatly simplified example of the arrangement. Let us suppose, therefore, that the transmitter contains only two valves, one arranged as an " oscillator " and the other as a " modulator."

The purpose of the oscillator is to generate H.F. currents which, when applied to the aerial, will set up wireless waves, while that of the modulator (or control valve) is to make these H.F. currents vary in sympathy with the L.F. currents which represent the sounds reaching the microphone.

The high-tension supply to the anodes of the oscillator and modulator is fed through a " choke

coil " from a common source. The choke keeps the current supply and the voltage across the two valves practically constant. Normally, therefore, the anode current through each valve is about the same. But if, by some means, the anode current through the modulator is increased that through the oscillator will be decreased by a corresponding amount, and vice versa.

When sounds reach the microphone, the current variations set up in the microphone circuit are made to act (via a transformer and amplifiers) on the modulator valve in such a way that its anode current varies in sympathy with the microphone currents representing sounds. We have seen that any increase or decrease in the current through the modulator valve brings about a corresponding decrease or increase, respectively, in the current through the oscillator valve. When, therefore, the modulator's anode current is made to vary in sympathy with the microphone currents, the current through the oscillator valve varies inversely with that through the modulator.

Now, the variations in the oscillator valve current produce corresponding variations in the H.F. oscillations generated by that valve. These, in turn, produce corresponding variations in the electro-magnetic waves which are set up by the H.F. currents oscillating through the aerial system.

As the amplitude of the modulated carrier-wave varies, by way of the somewhat indirect process outlined above, in sympathy with the variations in the microphone current, which in turn are produced by the sounds reaching the

microphone, it is clear that the modulated carrier-wave bears the imprint, so to speak, of those sounds.

At modern high-power stations, the transmitting aerial is often located at some little distance from the building which houses the transmitting set. Feeder lines lead the H.F. currents from the tuning arrangements of the transmitter to a high-frequency transformer connected to the aerial-earth system. In the case of twin-wave stations, such as the B.B.C. Regional stations, two independent transmitters and two separate aerial systems are used. At the Brookman's Park station, for example, one aerial radiates the London National programme on one wavelength, while the other aerial radiates the London Regional programme on another wavelength.

CHAPTER VII

HOW A TYPICAL RECEIVING SET WORKS

WHEN the wireless waves radiated from a transmitting station are intercepted by a receiving aerial, weak electrical impulses are set up in the receiving circuit, and these, by a roundabout process, finally cause sounds to be reproduced

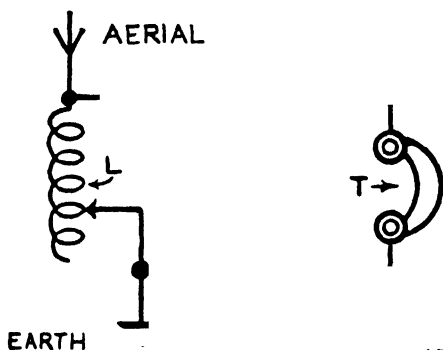


Fig. 15

through the medium of the headphones or loud-speaker.

The essential parts of a receiving installation in its simplest form comprise an aerial, earth-connexion, tuner, detector, and sound-reproducer. A simple crystal set, for instance, the circuit of which is shown in Fig. 15, is composed

of these parts. By means of the variable inductance, L , which forms the tuner, the aerial circuit is tuned so as to respond to waves of the length or frequency used by any station that it is desired to receive. The electrical impulses oscillating through the aerial-tuner-earth circuit are rectified by the crystal detector, D , so that they become unidirectional pulses of current which are capable of actuating the telephones, T , or headphones as they are more usually called. The varying low-frequency currents passing through the windings of the electromagnet arrangement inside the headphones exert a varying pull on the diaphragm and cause it to set up sound waves in the air.

Although the B.B.C. Regional scheme of high-power stations has given crystal sets a new lease of life, to some extent, they are gradually becoming more or less obsolete, and are certainly not representative of modern wireless receivers in general. For our present purpose, therefore, it would be best to take as an example for investigation, the working of a typical three-valve set comprising one H.F. valve, a detector valve, and one L.F. valve.

In the circuit shown in Fig. 16, the high-frequency valve is of the screen-grid type; the detector is of the ordinary three-electrode type; and the output valve is of the ordinary power type. A pentode valve could of course be used in the output stage if a very slight alteration was made to the circuit, but the ordinary triode power valve is shown here for the sake of simplicity.

The aerial tuner in this circuit consists of an inductance, L^1 , with a variable condenser, C^1 ,

shunted across it. The capacity of C^1 is made progressively variable from zero (or a negligible value) to, say, .0005 microfarads. The inductance by itself, or with the variable condenser at its minimum setting, tunes to a given wavelength. The variable condenser consists of two sets of metal plates (one set fixed, and the other movable), insulated from one another, but arranged so that they can be brought into mesh to the extent of completely overlapping without actually touching. As the moving plates are gradually moved into mesh with the fixed ones, the capacity of the condenser increases, and the wavelength to which the circuit responds increases proportionately.

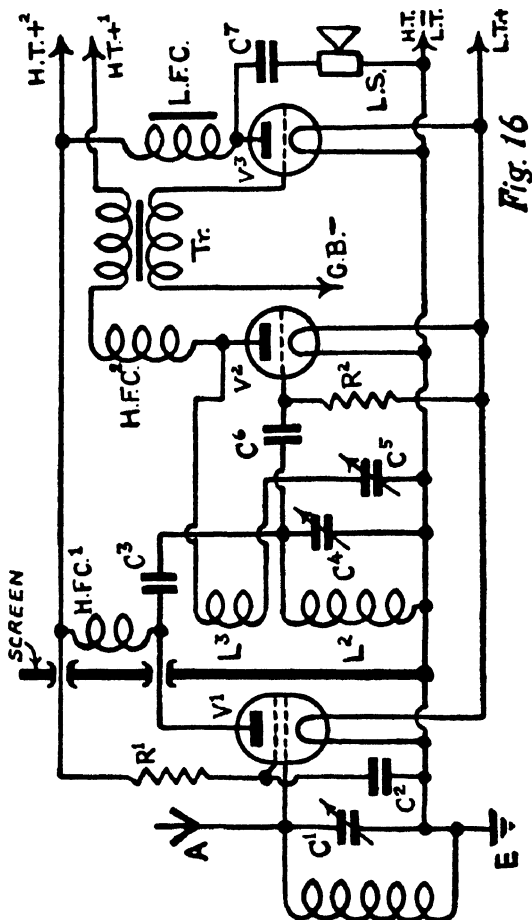
If, therefore, the coil tunes to, say, 200 metres with the condenser at its minimum setting, and to, say, 600 metres with the condenser at its maximum setting, it is clear that, by suitable adjustment of the condenser, a range of wavelengths extending from 200 to 600 metres can be covered. Should one wish to cover a different band of wavelengths—say, 1,000 to 2,000 metres—this can be accomplished with the same variable condenser by substituting a larger coil in place of the existing one. In many sets, interchangeable plug-in coils are used for tuning purposes, so that a large range of wavelengths can be covered at will. As an alternative to plug-in coils, one may employ a dual-range tuner which, by means of suitable switching, enables the effective amount of inductance in circuit to be increased or decreased.

The signals from the desired station having been selected by the tuner, they have next to be

amplified at high frequency by the screen-grid valve, V^1 , in the diagram. A screen-grid valve contains four electrodes, having a screening grid between the ordinary control grid and the anode. This screening grid, to which a fairly high positive potential (say, half the anode voltage) is applied, acts as an electro-static screen preventing any feed-back of energy from the anode circuit into the grid circuit. Such "feed-back" is in the nature of an unwanted reaction effect which might make the H.F. valve circuit produce oscillations that prevent the receiver working efficiently, and cause interference with other receiving sets in neighbouring houses.

The condenser C^2 , a fixed condenser of fairly large capacity—say, 1 mfd.—is a necessary part of the circuit, as without it the screening grid would act as a kind of anode and defeat its own ends. The high resistance, R^1 , serves to cut down the voltage applied to the screen grid to a suitable value, and also helps to prevent H.F. currents passing into the high-tension battery circuit.

By means of an external metal screen, at earth potential, which is usually arranged to coincide with the screening grid inside the valve bulb, the components associated with the anode circuit are completely screened from those in the grid circuit. Sometimes the whole H.F. stage is enclosed in a metal screening-box. Alternatively, a special S.G. valve with a metallic coating sprayed over the glass bulb may be used, the coils may be fitted with metal screening covers, and the components may be mounted on a metal chassis—all this metal screening being at earth potential.



The purpose of screening, which is carried out very extensively in many modern receivers, is to prevent unwanted interaction between the magnetic fields associated with the wiring and components in different parts of a circuit. Present-day sets are so efficient and sensitive that, in many cases, such interaction would upset the working of the whole circuit.

The intervalve coupling between the S.G. valve and the detector is of the choke-capacity type. The H.F. choke, H.F.C.¹, passes on the signals, after amplification by the S.G. valve, to the grid circuit of the detector by way of the coupling condenser, C³, which may be a fixed condenser of quite small capacity. The grid circuit of the detector valve is tuned by means of the inductance coil L² and the variable condenser, C⁴, adjustment of this condenser serving to bring the circuit into resonance with the aerial circuit L¹, C¹.

The detector valve, V², is arranged to work on the grid-leak and condenser, C⁶, principle. Rectification of the oscillating H.F. impulses in the grid circuit occurs between the filament and grid inside the valve, owing to the unidirectional flow of electrons between these two electrodes. The rectified voltage is produced across the grid-leak, R² (a high resistance of anything from, say, half a megohm to five megohms in value—one megohm, of course, being equal to a million ohms) which is connected between grid and filament outside the valve. The rectified output is then amplified by the detector valve, which really serves a dual purpose, acting as an L.F. amplifier as well as a rectifier.

The detector valve does not *completely* eliminate the H.F. component in the signal currents, and so any H.F. currents that get past the detector can be choked back by the high-frequency choke, H.F.C.², and utilised for the effect known as reaction by feeding them into the reaction coil, L³. The amount of reaction is controlled by the reaction variable condenser, C⁵. The reaction coil is coupled to (i.e. brought within the magnetic field of) the grid coil, L², and the effect of reaction is to feed back energy into the grid circuit so that it can be used twice over, so to speak, and thus increase enormously the total amplification of the signals.

If reaction is increased too much, the circuit "oscillates," very much like the oscillating valve in a transmitter, and causes squealing or howling noises as stations are tuned in, owing to the locally-produced oscillations "clashing," as it were, with the incoming carrier-waves. When used with care, however, reaction is of very real utility, especially when receiving weak signals from distant stations with a fairly small receiving set. In really powerful modern valve sets, though, there is a growing tendency to dispense with reaction, owing to the ample reserve of ordinary amplification afforded by ultra-efficient H.F. valve stages.

The L.F. transformer, Tr, serves to link up the detector with the low-frequency power valve, passing on the rectified signals to the grid of the latter. A negative bias, the value of which depends on the type of valve and the high-tension voltage used with it, is applied to the grid of the power valve by way of the L.F.

transformer secondary winding. This grid-bias serves the purpose of keeping the valve working on the correct portion of its characteristic curve, thus ensuring good-quality reproduction (if the anode potential is adequate) and cutting down the amount of high-tension battery current consumed by the valve.

An anode potential of at least 100 volts, as a rule (often much more) is applied to the plate of the power valve by way of the low-frequency choke, L.F.C. The amplified L.F. currents required to operate the loud-speaker find difficulty in passing through the choke, and take the much easier path offered by the condenser C' (a fixed condenser of large capacity—2 or 4 mfd.) and travel thence through the windings of the loud-speaker, LS, one terminal of which is connected to the earthed side of the filament circuit.

In passing through the windings of the loud-speaker, the "speech currents," as the final output of signals is sometimes termed, cause the electro-magnet arrangement inside the loud-speaker unit to exert a varying pull on the diaphragm, and the rapid backwards and forwards movement of the diaphragm sets up sound waves in the air. Thus the process of reproduction is completed.

The most popular types of loud-speaker at present are the balanced-armature cone type, the moving-coil, and the inductor dynamic speaker. In the case of a balanced-armature loud-speaker, the cone diaphragm is connected to an armature within the field of a permanent magnet. The armature is surrounded by a coil-winding on a small hollow bobbin, and the ends

of the winding are connected to terminals from which leads run to the receiving set. As long as no current, or only a steady direct current, is passing through the winding, the armature remains at rest; but when the varying currents representing wireless signals pass through the winding, they set up a varying magnetic field which causes the armature to vibrate. The movements of the armature are communicated to the diaphragm by means of a driving-rod, and the vibration or backwards and forwards movement of the diaphragm sets up sound-waves in the air.

In the case of a moving-coil speaker, the results are obtained on a rather different principle. The signal currents from the set pass through a coil-winding on a former which is attached to the diaphragm. The coil is free to move, within the strong magnetic field produced by a large "pot magnet." The ends of the moving coil are connected to the output circuit of the receiving set, and variations in the signal currents passing through the winding, bring about mechanical movements in the position of the coil. Since the latter is attached to the diaphragm, the diaphragm moves also, and its backwards-and-forwards vibration sets up sound-waves in the air.

An inductor dynamic speaker somewhat resembles the balanced-armature type in certain respects, but works on a rather different principle, and combines certain of the advantages of the balanced-armature type with those of the moving-coil type. Whereas some moving-coil speakers require a strong electric current, however, to energise the large magnet they contain, inductor dynamic speakers are always fitted with permanent magnets.

CHAPTER VIII

MAINS-OPERATED VALVES

THE use of electric supply mains as a source of power for radio purposes is becoming so widespread nowadays that no explanation of the principles underlying radio reception would be complete without some reference to the important subject of mains-operated receiving valves.

In what is popularly termed an "all-electric" or "all-mains" receiving set, the high-tension, low-tension, and grid-bias potentials are all derived from the electric supply mains, thus eliminating entirely the need for batteries and accumulators.

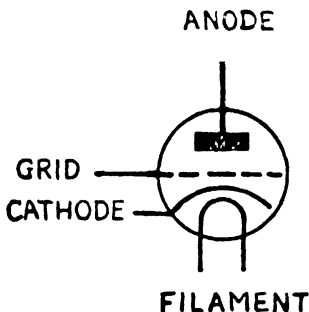
The majority of mains-operated valves are of what is known as the "indirectly heated" type. Let us compare these with ordinary battery-operated receiving valves.

The filament of an ordinary battery-operated valve, when heated by the passage through it of current from a suitable accumulator or battery, emits a steady, copious stream of electrons which, as we have already seen in previous chapters, are essential to the functioning of the valve.

An indirectly-heated mains valve, on the other hand, contains, in addition to the usual electrodes, a "*cathode*," which surrounds the filament, being interposed between it and the grid (as shown in a diagrammatic form in Fig. 17).

The cathode, when heated *indirectly* by heat radiated from the glowing filament, emits the steady stream of electrons which are required for the working of the valve.

The use of a separate cathode as an emitter is necessary in the case of valves of the mains-operated type when used as H.F. amplifiers,



. *Fig. 17*

detectors, etc., because the direct emission of electrons from the filament of a mains-operated valve is unsatisfactory for radio detection and amplification purposes, *except* in the final or output stage of the set, where a directly heated power valve may be used successfully.

Before the current supply from the mains can be utilised for radio purposes, it has to pass through certain processes which change its nature. The filament of a typical indirectly heated A.C. mains valve, for example, requires

an alternating current at a pressure of 4 volts. If, therefore, the electric mains supply is at a pressure of, say, 200 volts, this has to be "stepped down" to 4 volts, by means of a suitable transformer, before it can be applied to the filament circuit of the radio set.

The change of voltage effected by a transformer depends, as explained in Chapter V, on the ratio of primary turns to secondary turns. In order to give an output of 4 volts from the secondary when 200 volts are applied to the primary, the secondary winding has, of course, to contain much fewer turns of wire than the primary.

More than one secondary can be wound over the primary of a mains transformer, and consequently the arrangement can be made to give several outputs at different voltages (simultaneously, of course) if required.

Although alternating current is suitable for heating the filament of an A.C. valve, *direct* current is essential for the high-tension supply to the anode of this or any other valve. Therefore the A.C. must be changed into D.C. before it can be used for anode supply purposes. This is accomplished by means of a "rectifier."

There are several types of rectifiers working on different principles. The two most popular types are (1) metal rectifiers, in which the interaction between two sets of dissimilar metal plates, interleaved with one another, rectifies the current by allowing it to flow much more readily in one direction than in the other; and (2) valve rectifiers, which depend for their working on a one-way stream of electrons from the filament to one or two anodes.

Some rectifiers are arranged to work on the "half-wave" principle, only one-half of each complete alternation of the current being used, while others give "full-wave" rectification by making use of the two halves of each cycle.

In either case the resulting output is a series of pulses of D.C., which must be "smoothed out" into a steady, continuous flow of D.C. before the current can be applied to the anodes of the valves. The necessary smoothing is effected by means of a *filter*, which may comprise a choke-coil and large-capacity fixed condensers.

In most receivers it is only the output or power valve that requires the full voltage emerging from the rectifier and filter ; therefore a voltage regulator, containing suitable resistances, is usually employed to reduce the voltage, applied to the anodes of the remaining valves in the set, to an appropriate value.

There are several different methods by which grid-bias, also, may be derived from a mains supply, but the working of these is rather too complicated to describe in detail here.

CHAPTER IX

GRAMO-RADIO REPRODUCTION

THE electrical reproduction of gramophone records has gained widespread popularity among wireless amateurs, and a large number of receiving sets are now made in the form of radio-gramophones. Moreover, any existing wireless set of a suitable type can be adapted quite easily for electrical reproduction of records, in conjunction with an ordinary gramophone.

When playing records by the modern electrical method, which is, of course, a great improvement on the old-fashioned mechanical method of reproduction, a small electromagnetic device, known as a "pick-up," is used in place of the ordinary sound-box. Leads from the pick-up are connected to a low-frequency amplifier, or the L.F. part of a wireless set; the reproduction of the records is then heard by means of a loud-speaker.

A pick-up interprets the mechanical vibrations of the gramophone needle as a varying low-frequency current; it is not intended to produce any sound directly through the air, and so no tone-arm is required when playing records by the electrical method. A plain or jointed carrier-arm, specially shaped to give correct "needle-tracking," and pivoted on a supporting base intended to be mounted on the gramophone motor-board, is usually supplied with the pick-up. The price of a pick-up, complete with

carrier-arm, varies from a few shillings up to several guineas, according to the make and type.

One of the great advantages of the electrical reproduction of gramophone records is that the volume of sound is readily controllable. Many of the more expensive pick-ups incorporate a volume-control, which is fitted, say, inside the carrier-arm support. But with some of the cheaper models it is necessary to use an external volume-control to regulate the pick-up output. A volume-control of the high-resistance potentiometer type, connected across the pick-up terminals, enables one to regulate the output from a mere whisper up to full loud-speaker volume by simply turning a knob.

The design and construction of pick-ups vary rather widely with different makes, but the popular balanced-armature kind may be taken as typical. The pick-up contains a permanent magnet, to the ends of which pole-pieces are attached. A small armature, which forms a continuation of the needle-holder, is arranged in the little gap between the pole-pieces, and this armature is surrounded by a small coil of very fine wire, the ends of the winding being connected to the pick-up terminals, from which leads are taken to the volume control and thence to the input of the amplifier.

When the needle vibrates in sympathy with the sound-recording on the grooves of the record, it communicates these mechanical vibrations to the armature. (In one or two makes of pick-up the needle itself forms an armature.) The vibration of the armature within the field of the electro-magnet, sets up varying low-frequency currents in the coil-

winding which surrounds it. These feeble currents are passed to the amplifier, where they control much stronger currents (derived from the battery or mains supply) which in turn are passed through the loud-speaker windings, and, cause the loud-speaker diaphragm to vibrate, thus producing sounds.

The best method of connecting a pick-up to an amplifier or wireless set depends on the out-

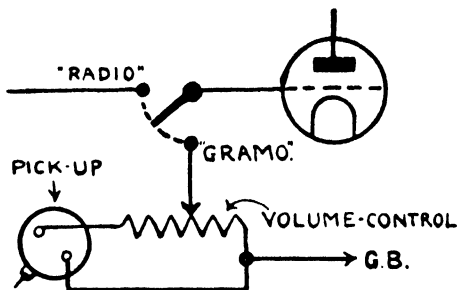


Fig. 18

put of the pick-up and the amount of low-frequency amplification available. As a general rule, however, two L.F. stages may be regarded as the minimum required to give a good volume of sound from a normal type of pick-up. A detector valve can be adapted quite easily to form the first L.F. amplifier for gramophone reproduction.

A simple and convenient way of connecting the pick-up in the grid circuit of a valve (either

detector or L.F.) is shown in Fig. 18. The necessary switching from radio to gramophone record reproduction and vice versa is done by means of a quick-action switch of a type expressly designed for gramo-radio work. There are several other methods of connexion, but that shown in the diagram is perhaps the simplest and most popular.

In certain cases it is advisable to insert a transformer between the pick-up and the grid circuit of the amplifying valve to which it is connected. When using a D.C. mains set, some such precaution is essential to avoid risk of shock when handling the pick-up. An input transformer with a 1 to 1 ratio can be used when it is required merely for the purpose of avoiding a direct connection between the pick-up and the grid circuit of the valve ; but if it is desired to increase the voltage output from the pick-up, a step-up transformer should be employed. Certain types of ordinary intervalve transformers are suitable for the purpose.

When the pick-up is a sensitive one giving a relatively big output, or when the voltage is stepped up by means of a transformer, care should be taken to avoid overloading the first L.F. valve, and to apply an adequate negative grid-bias.

CHAPTER X

SHORT-WAVE WIRELESS

ONE of the most remarkable developments in wireless during recent years is the gradual opening-up of communication on short waves below 100 metres. At one time these wave-lengths were believed to be useless for practical communication over any great distance. As a result of experiments, however, it was discovered that short waves, far from being useless, were in reality of the greatest practical value for easy and efficient communication over vast distances.

Nowadays, the short waves below 100 metres form the exclusive medium of communication for all the most important long-distance wireless services, such as the commercial radio-telegraph services; the overseas public telephone services, including those between England and Australia, the United States, etc., etc.; and the transmission of broadcast programmes from European countries for the benefit of their colonies in distant parts of the world.

The efficiency of short waves for long-distance communication is so remarkable that even small amateur transmitting stations, using extremely low power, are able to communicate with one another in morse and telephony over distances of thousands of miles.

Long-distance reception on the short waves can be carried out with very simple and

inexpensive apparatus. Even a simple two-valve set, for instance, when designed or adapted for short-wave reception, will enable a listener to hear short-wave transmissions from stations in America, Africa, Asia, and even Australasia, to say nothing of Europe itself!

Let us see why the short waves below 100 metres have such peculiar properties which do not apply to the remainder of the gamut of wavelengths used in wireless communication.

We know that the wireless waves radiated into space from the transmitting aerial of a medium-wave broadcasting station, such as the London Regional one at Brookman's Park, travel away in all directions, and become weaker as they get farther and farther from their source. If, for example, we erect a receiving aerial at a distance of some twenty-five miles from Brookman's Park, the currents set up in that wire by the incoming signals from the London Regional transmitter will be much weaker than they would be if we erected the aerial at a distance of only five miles from Brookman's Park.

In short-wave communication, however, the actual strength of signals does *not* decrease like that, in proportion to the distance from the transmitter. On the contrary, signals from stations working on wavelengths between, say, 15 and 50 metres, for instance, can often be heard at loud-speaker strength over a distance of several thousand miles, and at the same time they may be scarcely audible even on headphones at a distance of only a few hundred miles! In other words, the signal strength

gradually diminishes up to a certain distance from the station and then, at greater distances, it suddenly begins to increase again.

The only theory, at present, which seems to give a satisfactory explanation of this curious effect is that which supposes the existence of a reflecting layer (named the "Heaviside Layer") at a considerable distance above the earth's surface. This Heaviside layer is supposed to have the effect of reflecting wireless waves which travel upwards at an angle from the transmitting aerial, so that they are bent downwards again, so to speak, and strike the earth's surface at a considerable distance from the transmitter.

The direct radiation which seems to follow, more or less, the contour of the earth in travelling from the transmitting station, is soon weakened by absorption, etc. But the indirect rays which have passed upwards and have been reflected back again by the Heaviside layer, seem to lose little of their strength even after traversing thousands of miles.

The reflection of waves by the Heaviside layer varies enormously according to the length (or frequency) of the waves, and the distribution of daylight and darkness over the earth's surface between the transmitter and receiver. The latter point explains also the enormous variation between the day and night ranges of medium-wave broadcasting stations (i.e. stations working on the 200 to 600-metres waveband). Many distant stations that are nearly or quite inaudible on this waveband during the hours of daylight can be received at excellent strength after dark.

Results of recent investigations seem to point to the existence of a second reflecting layer at much greater altitude than the original Heaviside layer. It is believed that, under certain conditions, waves penetrate the first layer but are reflected by the second, and that the slightly delayed arrival of the waves, due to their having traversed a much greater distance, accounts for the curious "echo" effect which is sometimes observed when receiving certain short-wave signals.

Short-wave reception has already achieved enormous popularity among listeners in all parts of the world, and small wonder, in view of the fact that it is, in many respects, the most fascinating and interesting of all branches of radio reception. The arrangements for the provision by the B.B.C. of an Empire broadcasting service through their new short-wave station at Daventry (which supersedes the original G5SW, the short-wave transmitter at Chelmsford), has naturally given a great impetus to short-wave reception among listeners in distant parts of the British Empire.

Naturally it is impossible to do justice to such an important subject in the space of one chapter; but all the principal aspects of short-wave wireless, including the construction of special receiving sets and the adaptation of ordinary receiving sets, are described and explained in detail in a companion volume of this series: *Short-Wave Radio Reception*, by W. Oliver, 1/- net, W. Foulsham & Co., Ltd., London.

CHAPTER XI

PRACTICAL RADIO HINTS

THE regulations printed on every wireless receiving licence state that "the combined height and length of any external aerial shall not exceed 100 feet." In the days of low-powered broadcasting stations—when, too, the majority of listeners used crystal receivers—it was important to take full advantage of the maximum length of aerial permitted by the P.M.G.'s regulations.

Nowadays, however, a very long, high aerial wire is quite unnecessary in most cases. Owing to the gigantic power used by the principal European broadcasting stations, and the extreme efficiency of modern valve receivers, a single length of stranded copper wire (7-stranded 22 gauge, known as "7/22," for short), forming an aerial that has a combined length and height totalling 50 or 60 feet, generally gives ample signal strength. Some listeners find that a single length of, say, 20 feet of wire suspended vertically is sufficient for their requirements.

In all districts within easy range of the powerful twin-wave Regional stations of the B.B.C., a long aerial is not only unnecessary, but actually detrimental to results, as it increases the difficulty of "separating" twin-wave transmissions so as to receive the two alternative programmes without mutual interference.

Now for a few hints on the erection of an out-

door aerial. The accompanying diagrams (Figs. 19 to 22) show different methods of supporting a single-wire aerial of the popular "inverted-L" type. If you choose a tree as a support for the end of the wire farthest from the house, be careful to make sure that none of the twigs or leaves can touch the aerial wire, even in a high wind.

You will need two aerial insulators of which there are various types, the cheapest porcelain ones being obtainable for a penny or so apiece. The insulators have two holes in them, or a ring at each end. The end of the aerial wire is passed through one of the holes or rings, and twisted securely so that it cannot work loose. Through the other hole a length of stout galvanised iron wire is threaded and similarly secured; this wire acts as a halyard, and should be fastened to whatever aerial support is used—tree, mast, chimney stack, or what not.

A sufficient length of wire to form the vertical downlead has to be passed through one of the holes in the second insulator, and then twisted back on itself a few turns to secure it. A galvanised wire halyard is passed through the other hole in the insulator, and fastened to the house, so that the downlead hangs vertically a few feet from the wall of the house, with its end near the window of the room where the set is to be installed.

One of the halyards (that farthest from the house) should be tightened up so that the aerial is reasonably taut without an undue strain being placed on the wire.

Be careful that the wires on which the insulators are slung do not touch the aerial any-

FIG. 19.—AERIAL WHEN NEIGHBOUR'S HOUSE IS USED AS A SUPPORT.

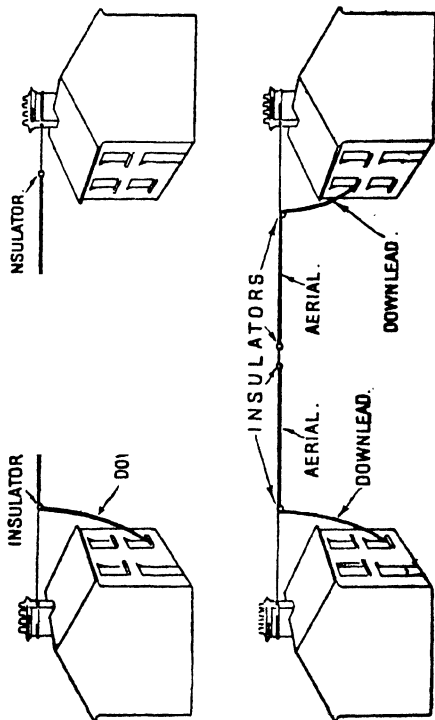


FIG. 20.—AERIAL WHEN NEIGHBOUR'S HOUSE IS USED AS A SUPPORT AND BOTH HOUSES HAVE A RECEIVING SET INSTALLED.

FIG. 21.—AERIAL USING HOUSE AND A TREE AS SUPPORTS.

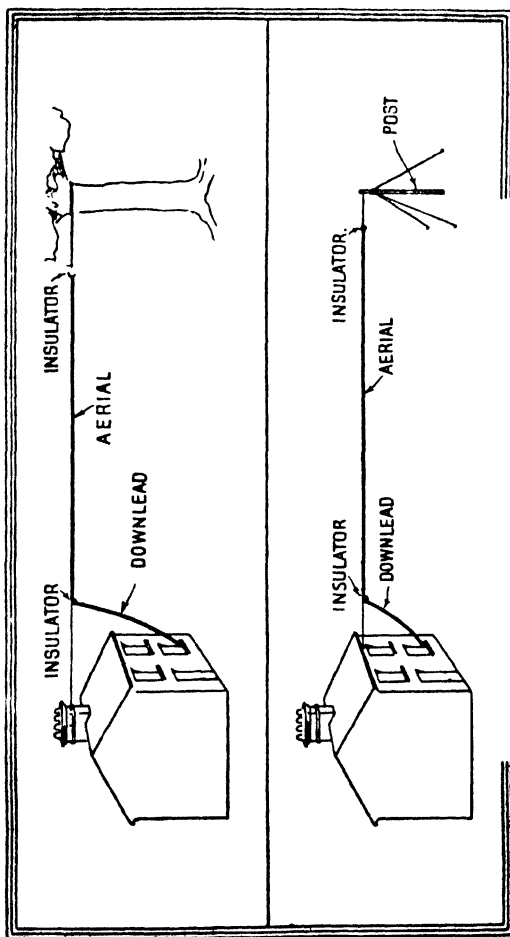
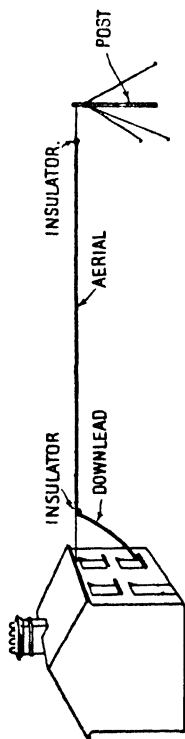


FIG. 22.—AERIAL USING HOUSE AND POST AS SUPPORTS.



where. The very object of the insulators is to prevent the aerial wire from touching anything else. Fig. 23 shows a typical aerial insulator.

Remember that there should be the greatest possible clear height from the ground to the aerial. If possible, avoid passing it over a house or building, because any wire, metal, or water in a house acts as the "earth," and so reduces the effective height of the aerial.

To bring the downlead into the house, bore a

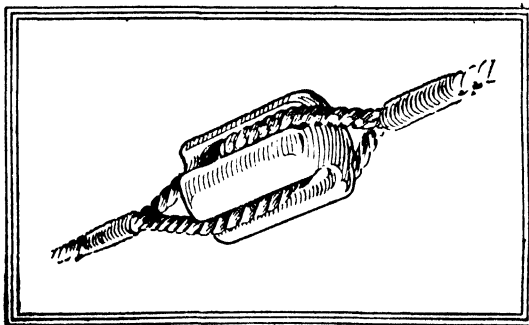


FIG. 23.

hole in the window or door-frame, and insert in this hole a tube made of some insulating material, such as ebonite, porcelain, or glass, slightly longer than the thickness of the frame. The lower end of the downlead may then be passed through this tube into the room: this is called the lead-in. Care should be taken so that wet cannot get through the hole. A better but more expensive arrangement is a special lead-in insulator, with a screw terminal at each end for attaching the wires to. The price is about 1s. 6d.

The best form of aerial is one in which the downlead is continuous with the horizontal portion thus **L** : this obviates the necessity for making a joint in the wire.

A good many listeners use indoor aerals. The electro-magnetic waves of wireless pass through bricks and mortar and wood, and it is that fact which makes indoor aerals possible. The wire, however, should be insulated.

There are many ways in which an indoor aerial may be erected. It may be stretched across the ceiling of an upper room, or even carried round the picture rail of the room in which your receiver is placed. To make it longer it may be carried round the ceiling of a loft or attic, brought down through the floor into a lower room, and carried round that room also. Ordinary staples should not be used for fastening the wire, but eye screws with insulator rings. Walls subject to much moisture from condensation and very damp rooms should be avoided.

A frame aerial consists of a few turns of insulated wire round the outer edge of two pieces of wood fixed together, on a stand so that the wire forms a square measuring about 3 feet or more on the side.

The advantage of a frame aerial is that it is portable and can be used either indoors or out, or carried about from place to place. But it is not of much use with a crystal receiver.

Now for a few general hints and notes of a practical nature.

Never use accumulators to the end of the charge. Keep them regularly charged ; even if you do not use them for a fortnight, give them

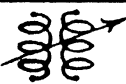
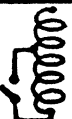
a small charge now and then. Accumulators last years if they are taken care of, but deteriorate rapidly if allowed to run down. Keep the terminals always clean and the screws hard up against the ends of the wires. Buy a copy of *Accumulators and Batteries*, published at 1/- net in Messrs. Foulsham's "Do It Yourself" series. This book will tell you how to keep your batteries in good running order.

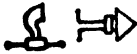
Do not handle a crystal unless absolutely necessary, and never do so with greasy hands. Grease and dirt greatly impair its sensitiveness.

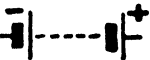
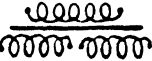
If intermittent, sizzling noises occur, they are probably due to atmospherics (i.e., electrical disturbances in the air), and you cannot do anything but possess your soul in patience until they stop. But if they are persistent and continuous, they are probably due to something else. It may be due to a loose connection somewhere, an L.T. or H.T. battery running down, or even to an accumulator that has been charged, and has not quite stopped gassing.

Never use a gas pipe as an "earth"—there is risk of fire or explosion in so doing.

APPENDIX

SYMBOLS USED IN CIRCUIT DIAGRAMS		
	EARTH 	 COUNTER- POISE
 FRAME AERIAL	 FIXED INDUCTANCE	 H.F. CHOKE
 VARIABLY COUPLED COILS	 COIL WITH TAPPINGS	 H.F. TRANSFORMER
 DUAL- RANGE TUNER	 FIXED CONDENSER	 VARIABLE CONDENSER
 DIFFERENTIAL CONDENSER	 FIXED RESISTANCE	 RHEOSTAT
 VARIABLE RESISTANCE	 POTENTIOMETER VOLUME CONTROL	 "FADER"

 AMMETER	 VOLTMETER	 MILLIAMMETER
 L.F. TRANSFORMER	 L.F. CHOKE	 CRYSTAL DETECTOR
 2-ELECTRODE VALVE	 3-ELECTRODE VALVE	 4-ELECTRODE (S.G.) VALVE
 PENTODE VALVE	 A.C. MAINS VALVE	 HEADPHONES
 LOUD SPEAKERS (HORN AND CONE)	 MICROPHONE	 GRAMOPHONE PICK-UP
 JOINED WIRES	 CROSSED WIRES	 ON-OFF SWITCH
 SINGLE-POLE DOUBLE-THROW SWITCH	 DOUBLE-POLE CHANGE-OVER SWITCH	 TRANSMITTING MORSE-KEY

		
TERMINALS	LIGHTNING ARRESTER	FUSE
		
CELL	L.T. BATTERY	H.T. BATTERY
		
DYNAMO	ALTERNATOR	MAINS SWITCH
		
FULL-WAVE VALVE RECTIFIER	MAINS TRANSFORMER	NEON LAMP
		
HALF-WAVE METAL RECTIFIER	FULL-WAVE METAL RECTIFIER	FLEXIBLE LEAD TWIN FLEX
		
SINGLE CIRCUIT OPEN JACK	PLUG	SOCKET
		
SINGLE CIRCUIT CLOSED JACK	SINGLE OPEN FILAMENT JACK	DOUBLE CIRCUIT JACK

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